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Character association and path analysis of grain yield in rabi sorghum [*Sorghum bicolour* (L.) Moench]

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Abstract
An investigation was carried out to understand the strength and direction of association of plant morphological, yield attributing traits and grain micro nutrient (Fe and Zn) content with grain yield per plant in *rabi* sorghum. The results of Correlation analysis suggested that the magnitude of genotypic correlation were higher as compared to their corresponding phenotypic correlations indicating the inherent relationship among the characters studied. Grain yield per plant expressed significant genotypic and phenotypic correlation coefficients with plant height (0.46** G, 0.45** P), number of leaves per plant (0.56** G, 0.54**P), number of nodes per plant (0.48** G, 0.44**P), leaf blade length (0.16** G, 0.16** P), leaf blade breadth (0.54** G, 0.51** P), ear head breadth (0.51** G, 0.46** P), 100–seed weight (0.70** G, 0.69** P) and fodder yield per plant (0.70** G, 0.68** P). This suggests that, these characters should be considered while selecting plants for grain yield improvement. Whereas ear head length (-0.26** G, -0.25** P) had significant negative association with grain yield per plant at both genotypic and phenotypic levels. High positive direct effect of plant height (0.51G, 0.16P), number of leaves (1.62G, 0.63P), leaf blade breadth (0.11G, 0.17P), ear head width (0.48G, 0.22P), 100 seed weight (0.03G, 0.28P) and grain Zn content (0.21G, 0.08P) on grain yield per plant at both genotypic and phenotypic level was observed, indicating importance of these characters and can be strategically used to improve the grain yield of sorghum.

Keywords: malnutrition, bio-fortification, micronutrients, path analysis, great millet

Introduction

Sorghum [*Sorghum bicolour* (L.) Moench] serves as major source of calories and nutrients to more than 300 million people and feed for cattle living in Asia and Africa. Sorghum being hardy and dependable crop that grows well under adverse conditions and can, thus play a major role in increasing food production in the semi-arid tropics. Presently it is cultivated in tropical, sub tropical and temperate regions of the world extending as many as six continents as ‘great millet’. In India it is grown as a dual purpose crop serving both grain and fodder requirements of the farming community and its regional importance as a major food crop is as much as that of wheat and rice.

India is a major producer of sorghum, which is cultivated on 5.79 million hectares (21 % of the global area) with an annual production of 5.55 million tons of grain (13 % of total global production) with the productivity of 1041.2 kg per hectare (Anon., 2015) [2]. In India, Maharashtra (2.86 million hectares and 2.27 million tonnes) and Karnataka (1.14 million hectares and 1.32 million tonnes) are major producer of sorghum, which is cultivated in both the *kharif* and *rabi* seasons.

The yields of *rabi* cultivars are lesser compared to *kharif* once due to moisture limiting situation. However most of the consumers prefer post rainy season sorghum for its superior grain quality attributing to good *roti* quality over rainy season. Post-rainy (*rabi*) sorghum varieties which are predominantly grown for food uses generally contain lower Fe and Zn content than that of rainy season sorghums (Ashok Kumar *et al.*, 2013b) [3]. One in three people in the world suffer from hidden hunger, caused by a lack of micro nutrients (Fe & Zn) and vitamins in their diets, which leads to negative health consequences (Kennedy *et al*., 2003) [12]. Hence improvement of *rabi* sorghum for grain yield and micro nutrient content (Fe and Zn) is an urgent need to reduce the risk of malnutrition among the people solely depend on sorghum crop for their dietary requirement.

Yield is a complex character controlled by polygenic loci, which depends upon many independent contributing characters. Knowledge of the magnitude and type of association between yield with its components themselves greatly help in evaluating the contribution of different components towards yield. Yield being a polygenic character is highly influenced by the fluctuations in environment. Hence, selection of plants based directly on yield would not be very reliable. Besides, the information on the nature of association between yield and its components helps in simultaneous selection for many characters associated with yield improvements (Mahajan *et al*., 2011) [15]. Path analysis provides information on the direct and indirect effects of various characters affecting yield.

Material and Methods

The present study comprised of 134 genotypes, consisting of selected accessions of mini core collection, red grain colored types, selected accessions of local germplasm lines, advanced breeding lines and released varieties which are maintained at AICRP on Sorghum, MARS, Dharwad. These genotypes were grown in two replications in a randomized block design (RBD) at AICRP on Sorghum, MARS Dharwad, during the post-rainy season in the 2013 crop season. The experiment was laid out on medium to deep black soils in two rows of 4 m length with 45 cm × 15 cm spacing. All agronomic practices were followed to raise a healthy crop.

In each replication five random plants from each entry were selected and labeled for recording morphological observations in field. Heads of the labeled plants were bagged with kraft paper bags prior to flowering to avoid pollen contamination and to harvest pure seed for assessing the micro nutrition content. Bagged heads were harvested separately at maturity; observations on yield attributing traits were recorded pre and post threshing. Utmost care was taken while threshing to avoid metal and soil contact to assure contamination free samples for micro nutrient analysis.

Samples from two biological replicates were drawn in each genotype. Manually ground sorghum flour using mortar and pistil were analyzed for grain micro nutrient content (Fe & Zn) following diacid digestion (HNO_3:$HClO_4$: 9:4), quantification of micronutrients were done with Atomic Absorption Spectrophotometer (AAS). Data on agronomic, yield and its component traits along with grain micro nutrient content were statistically analysed in WINDOSTAT ver8. software.

Results and Discussion

Genotypic and phenotypic correlation coefficients between the various morphological, yield attributing traits and grain micronutrients (Fe & Zn) traits, computed are presented in Table 1 and 2. Genotypic correlation coefficient provides measures of genetic association between traits and thus helps to identify the more important as well as less important traits to be considered in breeding programmes. For most of the association in this study, the genotypic correlation coefficients are higher than phenotypic correlation coefficients. Higher genotypic correlations of characters than phenotypic correlation coefficients had earlier been reported (Alhassan *et al*., 2008) [1]. Expressions of higher genotypic than phenotypic correlations are indications of strong inherent relationships between these characters (Johnson, 1955) [10]. However, when phenotypic correlations are higher than genotypic correlations, environmental effect or non-additive effects are acting on the trait in the same direction.

Correlation

Significant genotypic and phenotypic correlation coefficients were recorded between grain yield per plant with plant height (0.46** G, 0.45** P), number of leaves per plant (0.56** G, 0.54**P), number of nodes per plant (0.48** G, 0.44**P), leaf blade length (0.16** G, 0.16** P), leaf blade breadth (0.54** G, 0.51** P), ear head breadth (0.51** G, 0.46** P), 100–seed weight (0.70** G, 0.69** P) and fodder yield per plant (0.70** G, 0.68** P). Whereas ear head length (-0.26** G, -0.25** P) had significant negative association with this trait at both levels of probability. This suggests that, these characters should be considered while selecting plants for grain yield improvement. The significant negative association of grain yield per plant was observed with ear head length at both genotypic and phenotypic levels. This indicates, improvement of earhead breadth (r = 0.46** P) is more important than earhead length (r = -0.25** P) while addressing grain yield trait in sorghum.

Similar results were reported by Warkad *et al.* (2010) [22] that 1000 seed weight had highly significant positive association with grain yield per plant at both genotypic and phenotypic level. Mahajan *et al.* (2011) [15] also reported that grain yield per plant showed positive significant association with panicle width and test weight, Ashwini (2013) [5] reported seed yield per plant had positive significant association with plant height, ear head width, 100 seed weight and fodder yield at both levels. Daniel and Eric (2014) [6] reported that plant height, number of leaves, panicle width and weight of 100 grains had positive and significant correlation with grain weight per earhead.

Lower magnitude of negative correlation of grain yield per plant with grain iron (r = -0.09) and zinc (-0.09) in present study (Table 1 & 2) suggested the possible to enhance grain iron and zinc contents in high yielding backgrounds without any yield panalty, which was in agreement with the report of Reddy *et al.* (2005) [18], Reddy *et al.* (2010) [17], Ashok Kumar *et al.* (2012) [4] and Gayathri *et al.* (2012) [7] where they report negative association of grain yield with grain micro nutrient content.

Most of the agronomic traits evaluated in this study showed positive and significant correlation among themselves. For instance, there was positive significant correlation between plant height, number of leaves per plant, number of nodes per pant, ear head breadth, 100 seed weight and fodder yield per plant. Thus selection based on plant height and number of leaves will result in simultaneous improvement of fodder yield per plant and it can be very well exploited for development of high fodder yielding varieties in sorghum. Similar positive and significant correlation was reported by Jain and Patel (2012) [9] and Kalpande *et al.* (2015b) [11]. The results are in accordance with Sushil Kumar (2014) [19], who reported positive correlation of fodder yield with number of leaves per plant, leaf length, leaf width and panicle length.

Number of leaves per plant, plant height, number of nodes per pant, leaf blade breadth, grain yield per plant, ear head breadth, 100 seed weight and fodder yield per plant exhibited strong positive association among themselves. This indicates that there is greater relationship between number of leaves with larger leaf surface area, which results in higher photosynthesis thus improving source to sink relationship, which leads to increasing grain yield potential (Alhassan *et al.,* 2008, Jain and Patel. 2014b and Khandelwal *et al.,* 2015) [1, 8, 13].

Ear head breadth, plant height, number of leaves per plant, number of nodes per plant leaf blade length, leaf blade breadth, ear head length, 100-seed weight and fodder yield per plant were positively associated among themselves, suggesting possibility of simultaneous improvement of these traits by simple selection for any of the traits. Daniel and Eric (2014) [6] also reported that number of leaves per plant had positive and significant correlation with panicle width, plant height, weight of 100 grains, weight of grains per panicle and biological yield were positively correlated among themselves. The significant positive correlation among these traits suggests that these can be simultaneously improved without any compensatory negative effects.

Path analysis

Path analysis is the tool to partition the direct and indirect effects to measure the relative importance of factors involved. The estimation of correlation coefficient indicates the extent and nature of association between yield and its attributes, but does not show the direct and indirect effects of different yield attributes on yield. Grain yield is dependent on several component characters which are mutually associated, these will in turn impair the true association between a component and grain yield. A change in any one component is likely to disturb the whole network of cause and effect, thus each component has two paths of action *viz.*, 1) The direct influence on grain yield 2) Indirect effects through components which are not revealed from the correlation studies. In the present investigation, the path coefficient analysis was discussed at phenotypic level for some of the important characters.

The genotypic and phenotypic path analysis (Table 3 & 4) revealed the role of high positive direct effect of plant height, number of leaves, leaf blade breadth, ear head width 100 seed weight and grain Zn content on grain yield per plant among 134 genotypes. Significant positive correlation of grain yield per plant was recorded with all the above mentioned traits excluding grain Zn content indicating true relationship between these characters with grain yield per plant and direct selection for these traits will be rewarding for improvement of grain yield. In a similar study by Prakash *et al.* (2010) [16] who also reported that plant height had highest positive direct effect on grain yield per plant. Mohammad *et al.* (2012) and Vijaya *et al.* (2012) [21] observed direct effect of plant height and 1000-grain weight on grain yield. Kumar (2013) [14] also reported high direct effect of earhead length, earhead breadth, test weight and fodder yield on grain yield in sorghum.

It is interesting to note that grain Zn content had positive direct effect on grain yield per plant but it exhibited negative association with grain yield per plant due to high negative indirect contribution through number of leaves per plant and plant height. Likewise number of nodes per plant had negative direct effect on grain yield per plant but it exhibited positive association with grain yield per plant due to high positive indirect contribution through number of leaves per plant and plant height.

Taking into account of indirect effects, high and positive indirect effect was exhibited by number of nodes, fodder yield per plant, 100-seed weight, earhead length, plant height on yield and moderate positive indirect effect was exhibited by number of leaves per plant, grain total iron and zinc content. Results are in accordance with Susmita and Selvi. (2014b) who reported high positive indirect effects of 100 seed weight and total grain Fe content on grain yield. The residual effect in path analysis indicates that 62.00 per cent of variability is unaccounted and there might be few more characters other than those studied in the present investigation, which might have been responsible for influencing the grain yield of sorghum.

Table 1: Genotypic correlation coefficients of plant morphological, grain micro nutrient content (Fe & Zn) and productivity related traits in *rabi* of sorghum genotypes

Traits	Plant height (cm)	Number of leaves per plant	Number of nodes per plant	Leaf blade length (cm)	Leaf blade breadth (cm)	Earhead length (cm)	Earhead breadth (cm)	100 seed weight (g)	Fodder yield per plant (g)	Grain Fe (mg/kg)	Grain Zn (mg/kg)	Cor. With Grain yield per plant (g)
Plant height (cm)	1.00	0.44**	0.60**	0.10	0.12*	-0.12*	0.37**	0.48**	0.50**	-0.18**	-0.22**	0.46**
Number of leaves per plant		1.00	0.93**	0.04	0.39**	-0.43**	0.14*	0.52**	0.62**	-0.05	-0.18**	0.56**
Number of nodes per plant			1.00	-0.05	0.26**	-0.46**	0.12*	0.45**	0.56**	-0.26**	-0.18**	0.48**
Leaf blade length (cm)				1.00	0.48**	0.22**	0.19**	0.02	-0.02	0.18**	0.04	0.16**
Leaf blade breadth (cm)					1.00	-0.07	0.36**	0.52**	0.29**	-0.04	-0.07	0.54**
Earhead length (cm)						1.00	0.29**	-0.27**	-0.26**	0.09	0.23**	-0.26*
Earhead breadth (cm)							1.00	0.54**	0.55**	0.01	-0.16**	0.51**
100 seed weight (g)								1.00	0.70**	-0.01	-0.14*	0.70**
Fodder yield per plant (g)									1.00	0.04	-0.11	0.60**
Grain Fe (mg/kg)										1.00	0.07	-0.09
Grain Zn (mg/kg)											1.00	-0.10

Table 2: Phenotypic correlation coefficients of plant morphological, grain micro nutrient content (Fe & Zn) and productivity related traits in *rabi* of sorghum genotypes

Traits	Plant height (cm)	Number of leaves per plant	Number of nodes per plant	Leaf blade length (cm)	Leaf blade breadth (cm)	Earhead length (cm)	Earhead breadth (cm)	100 seed weight (g)	Fodder yield per plant (g)	Grain Fe (mg/kg)	Grain Zn (mg/kg)	Cor. With Grain yield per plant (g)
Plant height (cm)	1.00	0.43 **	0.55 **	0.09	0.10	-0.11	0.34 **	0.47**	0.48 **	-0.17 **	-0.19 **	0.45**
Number of leaves per plant		1.00	0.87**	0.02	0.37 **	-0.42**	0.15 *	0.51 **	0.59 **	-0.05	-0.16 **	0.54**
Number of nodes per plant			1.00	-0.07	0.24**	-0.43**	0.13 *	0.42 **	0.50**	-0.23 **	-0.15 *	0.44**
Leaf blade length (cm)				1.00	0.46**	0.21 **	0.15*	0.02	-0.02	0.17**	0.04	0.16**
Leaf blade breadth (cm)					1.00	-0.05	0.33 **	0.50 **	0.27 **	-0.03	-0.05	0.51**
Earhead length (cm)						1.00	0.26**	-0.26 **	-0.25 **	0.08	0.21 **	-0.25**
Earhead breadth (cm)							1.00	0.47**	0.47 **	0.04	-0.13 *	0.46**
100 seed weight (g)								1.00	0.68 **	-0.01	-0.13 *	0.69**
Fodder yield per plant (g)									1.00	0.03	-0.11	0.57**
Grain Fe (mg/kg)										1.00	0.08	-0.09
Grain Zn (mg/kg)											1.00	-0.09

Table 3: Genotypic path analysis of plant morphological, grain micro nutrient content (Fe & Zn) and productivity related traits in *rabi* of sorghum genotypes

Traits	Plant height (cm)	Number of leaves per plant	Number of nodes per plant	Leaf blade length (cm)	Leaf blade breadth (cm)	Earhead length (cm)	Earhead breadth (cm)	100 seed weight (g)	Fodder yield per plant (g)	Grain Fe (mg/kg)	Grain Zn (mg/kg)	Cor. with Grain yield per plant (g)
Plant height (cm)	**0.51**	0.71	-0.95	0.00	0.01	0.05	0.18	0.02	-0.08	0.06	-0.05	0.46**
Number of leaves per plant	0.23	1.62	-1.47	0.00	0.04	0.17	0.07	0.02	-0.10	0.01	-0.04	0.56**
Number of nodes per plant	0.31	1.51	-1.58	0.00	0.03	0.18	0.06	0.01	-0.09	0.08	-0.04	0.48**
Leaf blade length (cm)	0.05	0.06	0.09	-0.05	0.05	-0.09	0.09	0.00	0.00	-0.05	0.01	0.16*
Leaf blade breadth (cm)	0.06	0.63	-0.41	-0.02	0.11	0.03	0.17	0.02	-0.05	0.01	-0.01	0.54**
Earhead length (cm)	-0.06	-0.70	0.73	-0.01	-0.01	-0.40	0.14	-0.01	0.04	-0.03	0.05	-0.26**
Earhead breadth (cm)	0.19	0.23	-0.20	-0.01	0.04	-0.12	0.48	0.02	-0.09	0.00	-0.03	0.51**
100 seed weight (g)	0.24	0.85	-0.71	0.00	0.06	0.11	0.26	0.03	-0.11	0.00	-0.03	0.70**
Fodder yield per plant (g)	0.26	1.01	-0.89	0.00	0.03	0.10	0.26	0.02	-0.16	-0.01	-0.02	0.60**
Grain Fe (mg/kg)	-0.09	-0.07	0.41	-0.01	0.00	-0.04	0.01	0.00	-0.01	-0.30	0.01	-0.09
Grain Zn (mg/kg)	-0.11	-0.30	0.29	0.00	-0.01	-0.09	-0.08	0.00	0.02	-0.02	0.21	-0.10
Residual Effect = 0.5403												

Table 4: Phenotypic path analysis of plant morphological, grain micro nutrient content (Fe & Zn) and productivity related traits in *rabi* of sorghum genotypes

Traits	Plant height (cm)	Number of leaves per plant	Number of nodes per plant	Leaf blade length (cm)	Leaf blade breadth (cm)	Earhead length (cm)	Earhead breadth (cm)	100 seed weight (g)	Fodder yield per plant (g)	Grain Fe (mg/kg)	Grain Zn (mg/kg)	Cor. with Grain yield per plant (g)
Plant height (cm)	**0.16**	0.16	-0.14	0.01	0.02	0.02	0.08	0.13	0.02	0.02	-0.02	0.45
Number of leaves per plant	0.07	0.36	-0.22	0.00	0.06	0.07	0.03	0.14	0.03	0.01	-0.01	0.54
Number of nodes per plant	0.09	0.31	-0.25	0.00	0.04	0.07	0.03	0.12	0.02	0.02	-0.01	0.44
Leaf blade length (cm)	0.01	0.01	0.02	0.06	0.08	-0.04	0.03	0.00	0.00	-0.02	0.00	0.16
Leaf blade breadth (cm)	0.02	0.13	-0.06	0.03	0.17	0.01	0.07	0.14	0.01	0.00	0.00	0.51
Earhead length (cm)	-0.02	-0.15	0.11	0.01	-0.01	-0.17	0.06	-0.07	-0.01	-0.01	0.02	-0.25
Earhead breadth (cm)	0.05	0.05	-0.03	0.01	0.05	-0.04	0.22	0.13	0.02	0.00	-0.01	0.46
100 seed weight (g)	0.07	0.18	-0.10	0.00	0.08	0.04	0.10	0.28	0.03	0.00	-0.01	0.69
Fodder yield per plant (g)	0.08	0.21	-0.12	0.00	0.04	0.04	0.10	0.19	0.05	0.00	-0.01	0.57
Grain Fe (mg/kg)	-0.03	-0.02	0.06	0.01	-0.01	-0.01	0.01	0.00	0.00	-0.11	0.01	-0.09
Grain Zn (mg/kg)	-0.03	-0.06	0.04	0.00	-0.01	-0.04	-0.03	-0.04	-0.01	-0.01	0.08	-0.09
Residual Effect = 0.62												

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